Characterization and Mitigation of Radiation and High Temperature Effects in SiC Power Electronics, Phase I Project

SBIR/STTR Programs | Space Technology Mission Directorate (STMD)

ABSTRACT

Future NASA science and exploration missions require significant performance improvements over the state-of-the-art in Power Management and Distribution (PMAD) systems. Space qualified, high voltage power electronics can lead to higher efficiency and reduced mass at the system architecture level, and serve as an enabling technology for operational concepts such as solar electric propulsion. Silicon carbide (SiC) is a robust technology with superior electronic properties for power applications. SiC devices offer higher temperature operation, lower on-resistance, higher breakdown voltages, and higher power conversion efficiency than Silicon power devices. However, high vulnerability to heavy-ion induced degradation and catastrophic failure has precluded this promising technology from space PMAD applications. Importantly, physical mechanisms for this vulnerability are not well understood, resulting in the inability to develop radiation hardened SiC devices. CFDRC, in collaboration with Vanderbilt University and Wolfspeed, a Cree company, will utilize a coupled experimental and physics-based modeling approach to address this challenge. In Phase I, we will perform heavy ion testing of commercial Wolfspeed SiC Schottky diode and power MOSFET to generate response data. Detailed TCAD models for the diode will be developed, validated, and applied to identify physical mechanisms behind measured radiation response. In Phase II, we will focus on SiC power MOSFETs and perform additional heavy ion and total dose testing as a function of temperature and bias. Extensive TCAD modeling will be performed to identify radiation and temperature dependent response mechanisms, and to investigate device structure/process modifications for improved radiation hardness. Promising solutions will be prototyped followed by electrical/radiation characterization. Participation by Wolfspeed in Phase II and beyond will ensure superior space-qualified, SiC power MOSFETs for NASA applications.

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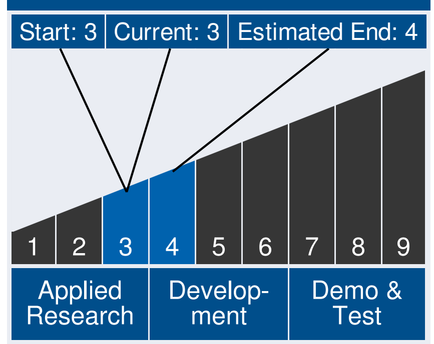
Technology Maturity



Management Team

Program Executives:
- Joseph Grant
- Laguduva Kubendran

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ANTICIPATED BENEFITS

To NASA funded missions:

Potential NASA Commercial Applications: Space qualified, high voltage/high temperature power electronics is directly aligned, per the NASA Space Power and Energy Storage Roadmap - Technology Area (TA) 03, with science and exploration missions such as: missions using electric propulsion, robotic missions, lunar exploration missions to Near Earth Orbit (NEO), robotic surface missions to Venus and Europa, polar Mars missions and Moon missions, and others. A higher operating voltage can yield a lower distribution system weight for the same power level and is highly desirable across many areas of PMAD. SiC devices offer higher breakdown voltage, lower switching losses, and increased temperature tolerance, all crucial features for NASA space power applications. The hardened SiC designs from this project will add to the NASA components library. The TA 03 roadmap identifies the development of analytical models and predictive tools to model and characterize power and energy storage systems as a Cross-Cutting Technology which will provide capability to all NASA missions that require power. Specifically highlighted is the need for physics-based models of power-related components. The modeling and analysis tools developed here directly address this need, and will help NASA better evaluate device performance under radiation and high temperature at an early stage, and design space qualified power electronics with better understanding and control of design margins, thereby reducing the development time and cost.

To the commercial space industry:

Potential Non-NASA Commercial Applications: Space qualified SiC power electronics will find application in power systems in all space-based platforms, including DoD space systems (communication, surveillance, missile defense), and commercial satellites. High voltage SiC power devices, through applications in inverters, high-voltage converters, motor drives, and switch

Management Team *(cont.)*

Program Manager:
- Carlos Torrez

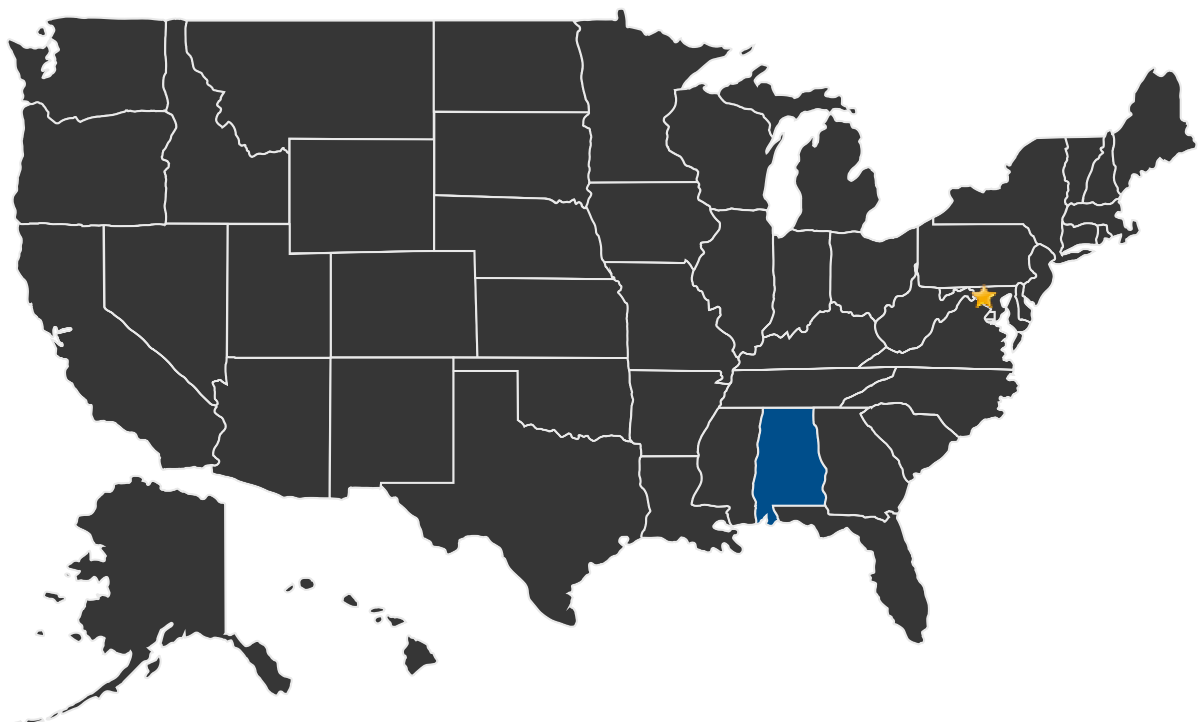
Principal Investigator:
- Ashok Raman

Technology Areas

Primary Technology Area:
Space Power and Energy Storage (TA 3)
└─ Cross Cutting Technology (TA 3.4)
  └─ Analytical Tools (TA 3.4.1)

mode power supplies, also offer significant performance benefits to power systems in other market sectors. These include national defense systems such as unmanned underwater vehicles (AUVs) and soldier portable power systems. Applications in the terrestrial energy sector include PMAD systems in all-electric and hybrid cars, grid-scale energy storage systems, smart grid, green energy systems (wind/solar systems), solid-state lighting, and remote, off-grid power systems (crewed vehicles and habitats). Other commercial applications of SiC include high temperature power and control systems for extreme environments such as geothermal drill sites and sensor systems in engines of aircraft and hybrid vehicles. For all the applications listed above, physics-based predictive and accurate modeling and design tools reduce the amount of required radiation/temperature testing, thus decreasing their cost, and time to market or field application.

U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Goddard Space Flight Center

Other Organizations Performing Work:

- CFD Research Corporation (Huntsville, AL)

PROJECT LIBRARY

Presentations

- Briefing Chart
    - (http://techport.nasa.gov:80/file/23169)

IMAGE GALLERY

Characterization and Mitigation of Radiation and High Temperature Effects in SiC Power Electronics, Phase I

DETAILS FOR TECHNOLOGY 1

Technology Title

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Potential Applications

Space qualified, high voltage/high temperature power electronics is directly aligned, per the NASA Space Power and Energy Storage Roadmap - Technology Area (TA) 03, with science and exploration missions such as: missions using electric propulsion, robotic missions, lunar exploration missions to Near Earth Orbit (NEO), robotic surface missions to Venus and Europa, polar Mars missions and Moon missions, and others. A higher operating voltage can yield a lower distribution system weight for the same power level and is highly desirable across many areas of PMAD. SiC devices offer higher breakdown voltage, lower switching losses, and increased temperature tolerance, all crucial features for NASA space power applications. The hardened SiC designs from this project will add to the NASA components library. The TA 03 roadmap identifies the development of analytical models and predictive tools to model and characterize power and energy storage systems as a Cross-Cutting Technology which will provide capability to all NASA missions that require power. Specifically highlighted is the need for physics-based models of power-related components. The modeling and analysis tools developed here directly address this need, and will help NASA better evaluate device performance under radiation and high temperature at an early stage, and design space qualified power electronics with better understanding and control of design margins, thereby reducing the development time and cost.